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STORAGE STABILITY OF SIX OSMOTICALLY DRIED, COMMERCIAL FRUIT PRODUCTS

by

Joseph Cohen
Tom C.S. Yang
Bonita Atwood

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In order to investigate osmotic drying for fruit products, six osmotically dried, commercial fruits were purchased from the CherryCentral Co. The products were whole pitted cherries, whole blueberries, whole strawberries, mango-flavored apple cubes, passion-fruit-flavored apple cubes and cherry/cinnamon-flavored apple slices. The products were stored at 40, 70, and 100° F. Sensory testing for overall acceptability, flavor, color, and texture was done initially with no storage as well as with samples that had been placed at accelerated 120 °F storage for one month. The criteria of a minimum score of 5.5 at the accelerated storage was used to determine acceptability for military use. All the samples held up well, although the strawberries both initially and at the later time were rated less than the other fruits. Samples were also withdrawn from storage at 1, 3, and 6 months and tested for reflectance color values as well as moisture loss and water activity. All the products tended to darken on storage as shown by the "L" values. The "a" and "b" values were less conclusive. Water activity showed no significant changes with storage. All the products appear to have lost moisture with 100 °F storage. It is concluded that osmotic drying and infusion as a process will yield improved fruit products for the military feeding system.

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PREFACE

The report describes tests conducted over a six-month period with six osmotically dried, commercial fruit products (pitted cherries, whole blueberries, whole strawberries, mango-flavored apple cubes, passion-fruit/cherry-flavored apple cubes and cherry/cinnamon-flavored apple slices.) The products were prepared by the CherryCentral Co., Traverse City, MI. The data for this report were collected by investigators from the U.S. Army Soldier Systems Command (SSCOM), Natick Research, Development and Engineering Center (NRDEC) from 1 August 1996 to 28 February1997.

The products were stored at 40, 70 and 100 ^{o}F (4, 21 and 38 ^{o}C). They were tested for percent moisture, water activity (A_W), and Hunter reflectance color (L, a and b) at storage times of one, three and six months as well as initially with no storage. In addition, sensory testing for overall acceptability, color, flavor and texture was conducted by untrained consumer panels for both the unstored products and the products that had been stored for one month at 120 ^{o}F (49 ^{o}C).

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STORAGE STABILITY OF SIX OSMOTICALLY DRIED, COMMERICAL FRUIT PRODUCTS

INTRODUCTION

The military services have a need for low and intermediate moisture foods of good nutrition and high sensory acceptability with a reduced cost of processing. Such foods will deliver a high density of nutrients, calories, etc. Osmotic dehydration, with the aid of vacuum infusion is such a low cost operation that has many advantages. The infusion of additional nutrients, such as vitamins and minerals, into the the food during the osmotic drying will further enhance the dried ration. The products would be processed at lowered temperatures, thus enhancing the sensory acceptability. Because of the lowered processing temperatures there would be less nutrient loss.

The authors previously studied (1995) the most important parameters that affect the drying process. They also demonstrated the feasibility of infusing nutrients into the food. They determined that osmotic drying and nutrient infusion would be a viable process for the military to use in the preparation of high quality foods.

The CherryCentral Co. manufactures commercial fruit products with this method. Consequently, the authors purchased six of their commercial items and placed them in storage so they could be studied in depth for consumer acceptability and stability. These products were made for extended shelf life with a fresh-like appearance and taste. However, they are for the commercial market that tends to require only an approximate nine-month shelf life. The military has more stringent requirements for both quality and storageability. The purpose of this study was to determine if the product met these requirements.

Products and Methods

A. Fruit Products

The products and their ingredients are listed by code letter in Table 1

TABLE 1 - FRUIT PRODUCTS AND INGREDIENTS

Code Product Description

A. Cherries

Whole, pitted cherries, approximately 0.5 - 0.75 in (1.2 - 1.8 cm).
Ingredients - cherries, sugar, sunflower oil

B. Blueberries

Whole, approximately 0.25 - 0.38 in (0.6 - 0.9 cm).
Ingredients - blueberries, fructose, corn syrup, malic acid, sunflower oil

C. Strawberries

Whole, approximately 0.75 - 1.25 in (1.8 - 3.0 cm)
Ingredients - strawberries, fructose corn syrup, blueberry juice concentrate, malic acid, sunflower oil

D. Mango Flavored Apple Cubes

Approximately 0.25 in (0.6 cm)
Ingredients - apples, high fructose corn syrup, ascorbic and citric acid, (to maintain color), salt, natural flavors, color added, sunflower oil

E. Passion-Fruit/Cherry Flavored Apple Cubes

Approximately 0.25 in (0.6 cm)
Ingredients - apples, sugar, cherry juice concentrate, ascorbic and citric acid (to maintain color), salt, natural flavors, sunflower oil

F. Cherry/Cinnamon Flavored Apple Chips

Approximately 0.75 - 2.0 in (1.8 - 5.0 cm) x 0.13 in (0.3 cm) in thickness
Ingredients - apples, sweetened cherry juice (cherry juice, sugar), natural cinnamon flavor

B. Method of Manufacture

All the products were prepared from fresh fruit by initially drying by osmosis in a concentrated sweetener solution. The flavors were infused during the osmotic drying. The drying was finished in a convection dryer at 200 ^{o}F (93 ^{o}C). Sunflower oil was added as a processing aid to keep the products free flowing.

All the products were packaged in clear laminated film supplied by the American National Can Co. to the following specifications.

MVTR (moisture vapor transmission rate) - 0.3 g/100 sq in/24 hours at 100 F and 90% relative humidity

Oxygen transmission - 0.6 cc/100 sq in/24 hrs and 0% relative humidity.

C. Storage

The products were all stored at 40, 70 and 100 ^{o}F (4, 21 and 38 ^{o}C) as well as a smaller quantity at 120 ^{o}F (49 ^{o}C) accelerated storage. It is generally accepted that one month storage at 120 ^{o}F is equivalent to three years at 70 ^{o}F (room temperature).

D. Testing

1. Sensory Measurements

Testing was done at Natick by the regular untrained consumer panel consisting of 36 - 37 participants. The products were tested by two panels. Panel 1 tested the whole fruit (products A, B, C). Panel 2 tested the apple (products D, E, F). There was some overlap of the panel participants, but it was not complete.

The panelists evaluated the acceptability of the flavor, texture, and color of the products, as well as their overall acceptability, using a 9-point hedonic scale ranging from 1-dislike extremely to 9-like extremely, with 5-neither like nor dislike. They were also asked to comment on the products. The testing was done with unstored fruit and repeated with fruit that had been stored for one month at 120 ^{o}F.

2. Physical Measurements

a. Water Activity

Water activity was measured using an Aqua Lab Model CX-2™ meter. All readings were done in duplicate.

b. Percent Moisture

The percent moisture was determined with two methods. The first used a Computrac Max-50™ radiant heating moisture analyzer and made a single measurement. The second used standard AOAC vacuum oven methods (1995). The value reported is the average of duplicate measurements on a single sample.

c. Reflectance Color

A Pacific Systems Spectrogard Reflectometer, Model 96™ was used for these methods. A glass cell of dimensions 1 x 1.5 in x 3/16 in thick (2.5 x 3.8 x 0.8 cm thick) was used to hold the samples being measured. Single readings were taken on each side of the cell and then repeated with a fresh sample. Hunter "L", "a" and "b" measurements were made. A greater "L" indicates a lighter color, a greater negative "a" indicates more red, less green and a greater "b" indicates more yellow, less blue.

Results and Discussion

A. Sensory

Table 2 shows the scores without storage. Table 3 shows the scores after 1 month of storage at 120 ^{o}F. (In both tables, the products are coded as in Table 1.)

TABLE 2. NO STORAGE TIME

Table 2a. Overall Acceptability

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	7	4	1	1	2	3
8	9	3	2	7	5	3
7	8	11	6	3	8	10
6	4	7	5	9	3	8
5	4	3	2	8	4	2
4	3	5	8	4	7	6
3	0	2	3	1	5	0
2	1	1	5	2	2	4
1	0	0	3	1	0	0

Table 2b. Flavor

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	7	6	3	2	1	4
8	9	3	3	5	7	5
7	5	12	5	3	6	9
6	7	7	5	10	5	8
5	4	1	2	9	2	4
4	1	5	5	4	10	3
3	2	0	7	1	4	1
2	1	2	3	2	1	2
1	0	0	3	0	0	0

(Continued)

TABLE 2. NO STORAGE TIME (CONTINUED)

Table 2c. Color

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	5	4	0	4	3	4
8	10	5	4	4	3	2
7	4	6	2	10	3	7
6	11	10	2	3	9	12
5	3	6	5	13	8	5
4	2	3	11	0	6	4
3	1	1	5	2	2	0
2	0	1	5	0	2	2
1	0	0	2	0	0	0

Table 2d. Texture

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	6	3	2	2	1	2
8	12	3	2	6	6	3
7	8	7	3	4	7	6
6	7	7	5	3	5	9
5	3	9	8	7	6	4
4	1	3	8	6	6	4
3	0	3	3	5	4	1
2	0	1	4	2	1	5
1	0	0	1	1	0	2

TABLE 3. 1 MONTH STORAGE AT 120 °F

Table 3a. Overall Acceptability

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	0	0	1	0	0	1
8	5	3	3	8	1	4
7	8	9	4	12	2	7
6	6	7	2	5	7	6
5	7	9	7	7	10	7
4	6	2	9	3	6	6
3	3	4	7	1	9	3
2	1	2	4	1	1	2
1	0	0	1	0	1	1

Table 3b. Flavor

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	4	1	1	0	1	0
8	3	3	1	1	0	5
7	15	12	7	6	7	4
6	4	9	11	6	9	9
5	6	6	4	3	5	5
4	2	2	6	10	8	9
3	0	2	3	6	6	5
2	2	1	3	5	1	0
1	0	0	0	0	0	0

(Continued)

TABLE 3. 1 MONTH STORAGE AT 120 ^{o}F (Continued)

Table 3c. Color

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	4	1	1	0	0	2
8	5	4	3	2	1	5
7	10	6	2	8	7	7
6	6	10	8	8	11	10
5	6	5	5	10	4	5
4	0	8	8	2	9	5
3	3	1	4	4	4	3
2	1	1	5	2	1	0
1	1	0	0	1	0	0

Table 3d. Texture

	Number of Scores per Product (Code)					
Score	A	B	C	D	E	F
9	2	1	0	0	1	0
8	7	0	2	1	0	5
7	14	8	5	6	7	4
6	5	9	3	6	9	9
5	4	6	8	3	5	5
4	1	10	9	10	8	9
3	3	1	4	6	6	5
2	0	0	3	5	1	0
1	0	1	2	0	0	0

Table 4 is a summary of the data analysis for the sensory testing by product. Significance is reported at 95 or 99% levels.

TABLE 4. OVERALL ACCEPTABILITY, FLAVOR, COLOR, TEXTURE SENSORY TESTING, PER PRODUCT

	Overall Acceptability		Flavor		Color		Texture	
	initial	1 mo.	initial	1 mo.	initial	1 mo.	initial	1 mo.
4a - Cherries								
N	36	36	36	36	36	36	36	36
Mean Score	6.92	5.61	6.78	6.42	6.81	6.22	7.17	6.53
Stand. Dev. ±	1.76	1.66	1.88	1.71	1.56	1.95	1.30	1.56
F	10.5		0.72		1.92		3.57	
Significance	99%		nsd		nsd		nsd	
4b - Blueberries								
N	36	36	36	36	36	36	36	36
Mean Score	6.17	5.50	6.47	6.03	6.25	5.69	5.83	5.36
Stand. Dev. ±	1.81	1.66	1.87	1.52	1.71	1.60	1.76	1.53
F	4.73		2.93		4.06		3.04	
Significance	95%		nsd		95%		nsd	
4c - Strawberries								
N	36	36	36	36	36	36	36	36
Mean Score	4.58	4.39	4.89	5.31	4.28	4.83	4.86	4.58
Stand. Dev. ±	2.21	1.84	2.44	1.74	1.97	1.90	1.99	1.84
F	0.66		0.14		0.02		1.16	
Significance	nsd		nsd		nsd		nsd	

Comment: The overall acceptabiity was significantly less upon storage, but as it was greater than 5.5, it was still acceptable.

Comment: There was a significant lowering of each characteristic, including overall acceptability, with storage. The blueberries were still acceptable.

Comment: The strawberries had lower ratings than all the other products. This will eliminate the strawberries from further acceptability studies. (However, they are a commercial product that has significant sales.) There was no significant change with storage.

TABLE 4. OVERALL ACCEPTABILITY, FLAVOR, COLOR, TEXTURE SENSORY TESTING, PER PRODUCT (Continued)

	Overall Acceptability		Flavor		Color		Texture	
	initial	1 mo.	initial	1 mo.	initial	1 mo.	initial	1 mo.
4d - Mango Flavored Apple Cubes								
N	36	37	36	37	36	37	36	37
Mean Score	5.67	6.22	5.75	4.57	6.31	5.22	5.31	4.57
Stand. Dev. ±	1.90	1.55	1.73	1.76	1.60	1.77	2.15	1.76
F	0.47		1.63		9.60		4.43	
Significance	nsd		nsd		99%		nsd	
4e - Passion Fruit/Cherry Flavored Apple Cubes								
N	36	37	36	37	36	37	36	37
Mean Score	5.53	4.54	5.58	5.11	5.56	5.22	5.67	5.35
Stand. Dev.	2.05	1.52	1.93	1.61	1.83	1.49	1.84	1.65
F	7.71		1.29		1.84		3.47	
Significance	1%		nsd		nsd		nsd	
4f - Cherry/Cinnamon Flavored Apple Chips								
N	36	37	36	37	36	37	36	37
Mean Score	5.86	5.38	6.28	5.35	6.06	5.97	5.25	5.35
Stand. Dev.	1.99	1.92	1.85	1.62	1.72	1.64	2.23	1.64
F	2.25		0.06		0.60		0.09	
Significance	nsd		nsd		nsd		nsd	

Comment: The overall acceptability and flavor were not significantly affected by storage. Actually, the overall acceptability increased with storage, although not significantly. There might be some changes occurring during storage that are not understood. It also might indicate that the sensory panel is not as discriminatory as would be liked. Color and texture scores decreased with storage.

Comment: The overall acceptability of this product decreased with storage, dropping out of the acceptable range. There was no other significant differences.

Comment There were no significant differences with storage.

A comparison of the sensory data for all the products is given in Figures 1 - 4. The bold lines show the positions for scores of 5 and 6.

B. Water Activity

At each withdrawal, water activity was measured in duplicate. The results as given in Table 5 are the mean of the two readings.

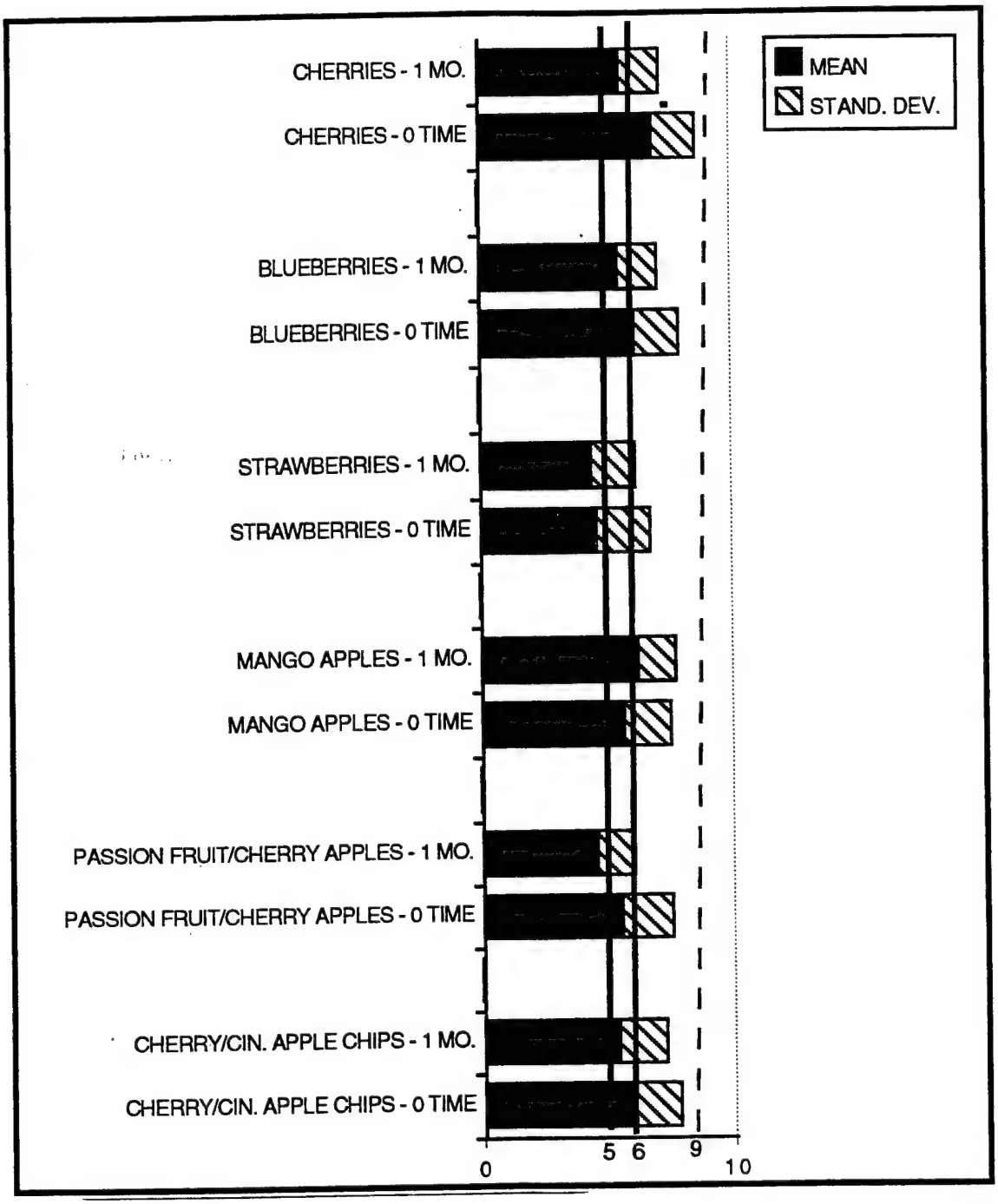


FIGURE 1 - OVERALL ACCEPTABILITY COMPARISON

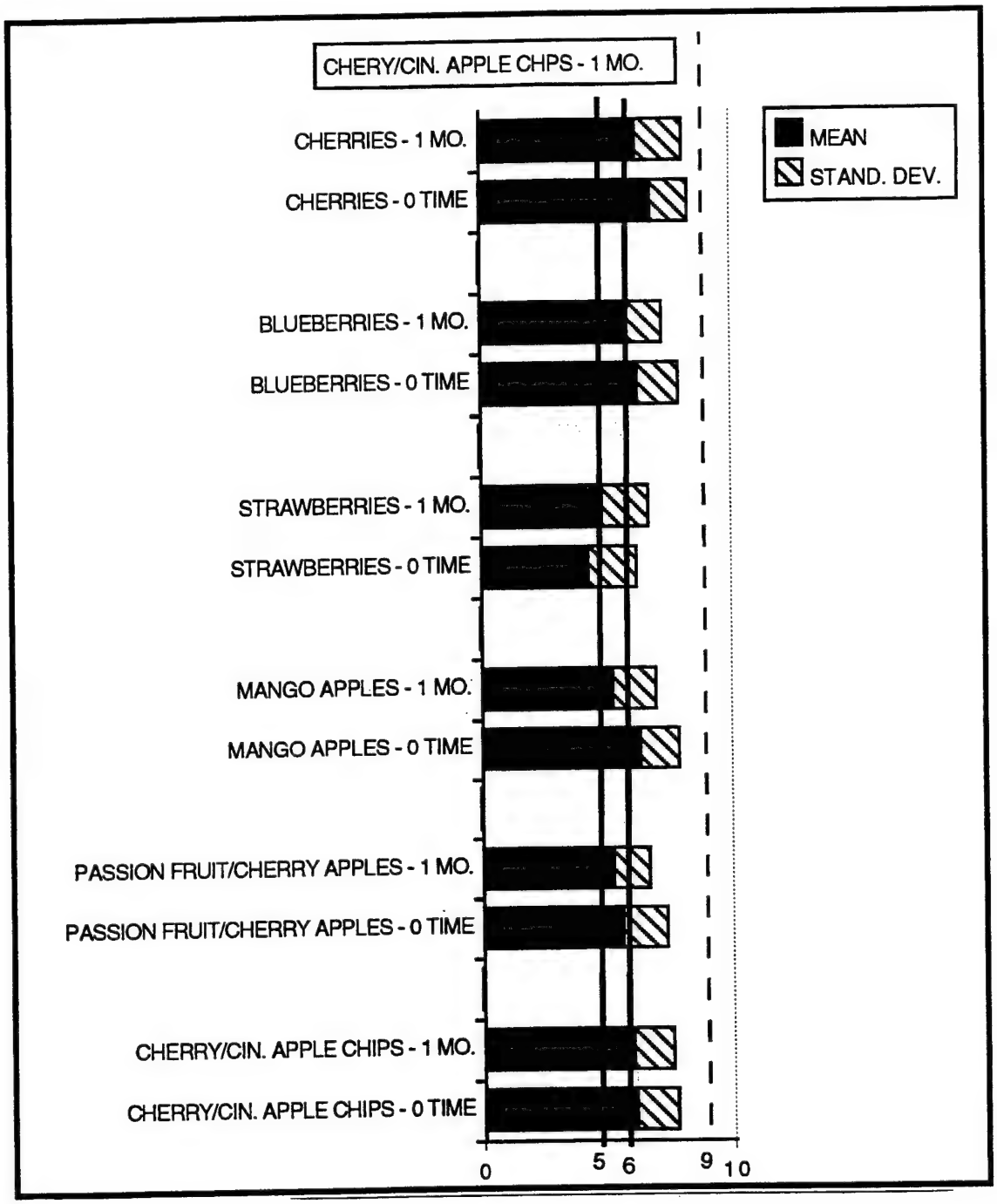


FIGURE 2 - COLOR COMPARISON

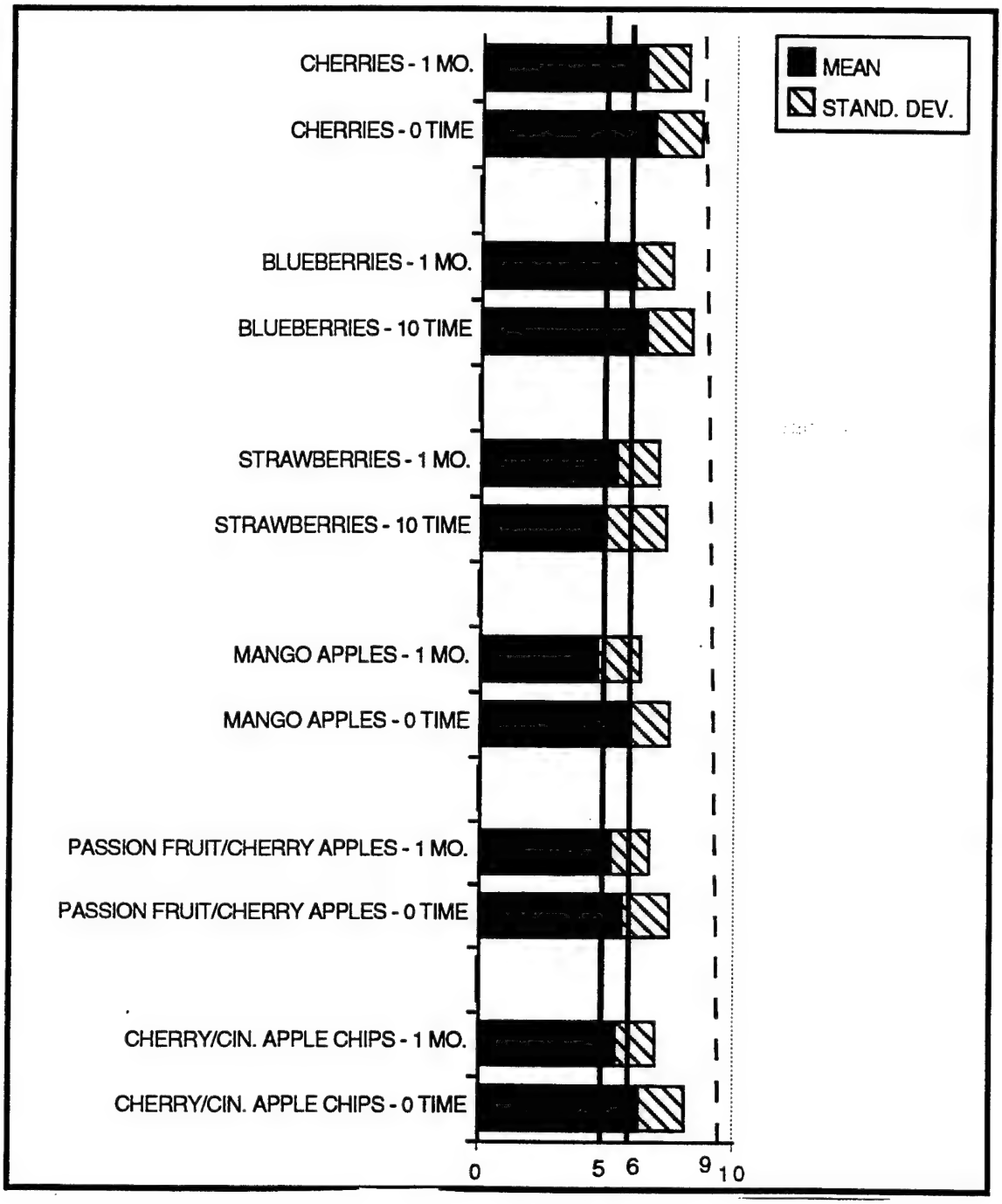


FIGURE 3 - FLAVOR COMPARISON

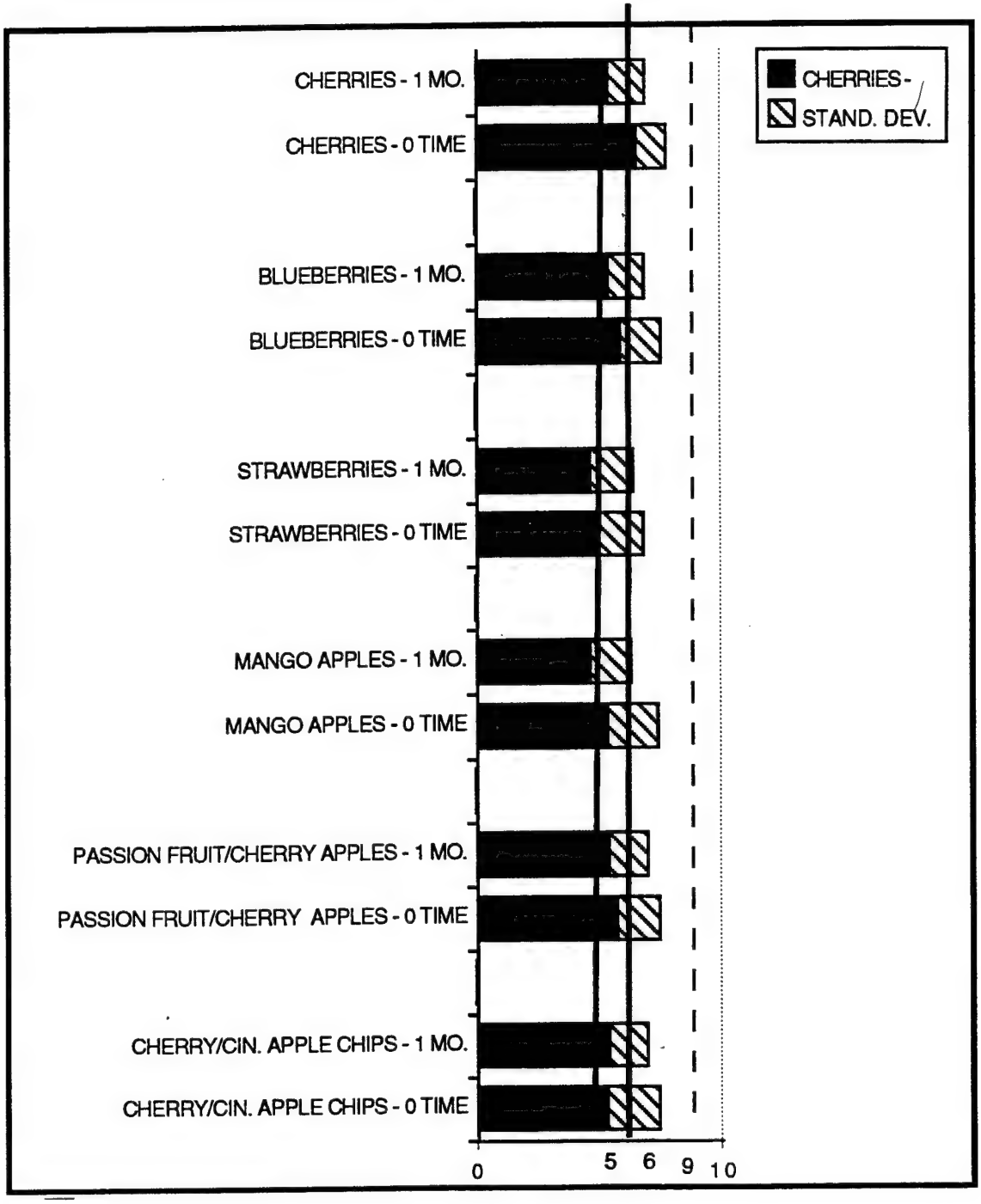


FIGURE 4 - TEXTURE COMPARISON

TABLE 5 WATER ACTIVITY MEASUREMENTS

Storage Temp. °F	Storage Time, mo.	Product A	B	C	D	E	F
NA	0	0.61	0.61	0.61	0.44	0.46	0.49
120	1	0.57	0.54	0.56	0.46	0.47	0.43
100	1	0.64	0.68	0.62	0.45	0.46	0.46
70	1	0.62	0.61	0.62	0.46	0.43	0.44
40	1	0.62	0.64	0.66	0.45	0.50	0.50
100	3	0.43	0.41	0.39	0.26	0.25	0.24
70	3	0.54	0.47	0.49	0.27	0.27	0.26
40	3	0.57	0.48	0.49	0.28	0.28	0.26
100	6	0.46	0.41	0.44	0.32	0.31	0.31
70	6	0.57	0.50	0.57	0.36	0.38	0.35
40	6	0.57	0.52	0.57	0.34	0.35	0.33
Mean of data by time and temperature °F							
1 mo		0.63	0.64	0.63	0.45	0.46	0.47
3 mo		0.51	0.45	0.46	0.27	0.27	0.25
6 mo		0.53	0.48	0.53	0.34	0.35	0.33
100		0.51	0.50	0.48	0.34	0.34	0.34
70		0.58	0.53	0.56	0.36	0.36	0.35
40		0.59	0.55	0.57	0.36	0.38	0.36

Table 6 is the data analysis for the water activity measurements.

TABLE 6. TIME AND TEMPERATURE ANALYSIS FOR WATER ACTIVITY

Factor	Product (Code) A	B	C	D	E	F
Time						
F	0.22	0.01	0.03	0.22	0.47	0.93
significance	nsd	nsd	nsd	nsd	nsd	nsd
Temperature						
F	0.01	0.28	0.13	0.00	0.22	0.24
significance	nsd	nsd	nsd	nsd	nsd	nsd
Time x Temperature						
F	2.36	1.83	0.72	0.51	0.00	0.04
significance	nsd	nsd	nsd	nsd	nsd	nsd

The data analysis above indicates no significant change due to storage time and temperature for water activity measurements for any of the products.

C. Percent Moisture

At each withdrawal the percent moisture of the products was measured with two methods. Table 7 presents the measurements using the vacuum oven method. Table 8 presents the measurements using the radiant heating method.

TABLE 7. PERCENT MOISTURE WITH VACUUM OVEN METHOD

Storage Temp., F	Storage Time, mo.	Product (Code) A	B	C	D	E	F
NA	0	17.0*	19.9*	13.8*	8.1*	9.6*	7.8*
120	1	15.5	12.7	12.2	4.9	6.8	5.7
100	1	16.6	15.0	14.3	5.5	7.5	6.2
70	1	17.8	16.1	16.1	5.9	7.5	7.3
40	1	18.2	14.7	16.0	5.9	7.7	6.4
100	3	15.2	14.2	13.0	6.0	7.4	6.9
70	3	17.7	15.7	15.8	6.9	8.6	6.2
40	3	17.6	15.0	14.6	5.9	7.7	6.5
100	6	16.9	8.8	10.0	4.4	6.0	4.2
70	6	17.1	15.8	15.5	7.0	8.8	7.4
40	6	17.0	15.6	15.8	6.8	8.0	6.8

* Estimated value

Mean of Data by Time and Temperature °F

1 mo	17.5	15.3	15.5	5.8	7.6	6.6
3 mo	16.8	15.0	14.5	6.3	7.9	6.5
6 mo	17.0	13.4	13.8	6.1	7.6	6.1
100	16.2	12.7	12.4	5.3	7.0	5.8
70	17.5	15.9	15.8	6.6	8.3	7.0
40	17.6	15.1	15.5	6.2	7.8	6.6

TABLE 8. PERCENT MOISTURE WITH RADIANT HEATING METHOD

Storage Temp., °F	Storage Time, mo.	Product (Code) A	B	C	D	E	F
NA	0	25.6	26.9	22.2	10.4	18.4	14.0
120	1	23.3*	17.1*	19.6*	6.3*	13.0*	10.2*
100	1	25.0*	20.2*	23.0*	7.1*	14.4*	11.1*
70	1	26.7*	21.8*	25.9*	7.6*	14.4*	13.0*
40	1	27.4*	19.8*	25.8*	7.5*	14.8*	11.5*
100	3	24.5	22.8	20.4	7.1	14.5	10.5
70	3	27.1	26.5	26.3	8.8	14.5	12.0
40	3	24.8	26.9	26.7	8.1	13.7	11.1
100	6	16.9	9.8	18.1	6.0	13.3	9.8
70	6	24.5	16.5	22.0	9.4	16.8	15.0
40	6	28.2	19.2	22.8	8.1	16.4	14.3
Mean of Data by Time and Temperature °F							
1 mo		26.2	20.6	24.9	7.4	14.5	11.8
3 mo		25.5	25,4	24.5	8.0	14.2	11.2
6 mo		23,2	15.2	20.9	7.8	15.5	13.0
100		23.1	17.6	20.5	6.7	14.1	10.5
70		26.1	21,6	24.7	8.6	15.2	13.3
40		26.8	21.9	25.1	7.9	15.0	12.3

* Estimated value.

At zero time, moisture was determined only by the radiant heating method. At 1 month moisture was determined only by the vacuum oven method. At 3 and 6 months both methods were used to determine moisture. In order to estimate the missing values the data for 3 and 6 months was used to determine a ratio of vacuum oven to radiant heating for each product. The values thus determined are shown in Table 9:

TABLE 9 - RATIO OF VACUUM OVEN AND RADIANT HEATING DRYING METHODS

Code and Product	Ratio	Range of Ratio
A. Cherries	0.665	0.603 - 0.710
B. Blueberries	0.740	0.558 - 0.958
C Strawberries	0.623	0.547 - 0.705
D. Mango Flavored Apple Cubes	0.779	0.728 - 0.845
E. Passionfruit/Cherry Flavored Apple Cubes	0.521	0.451 - 0.593
F. Cherry/Cinnamon Flavored Apple Chips	0.588	0.451 - 0.593

Tables 10 and 11 are the time and temperature analysis for the moisture measurements.

TABLE 10 - TIME AND TEMPERATURE ANALYSIS FOR PERCENT MOISTURE AS DETERMINED BY VACUUM OVEN METHOD

	Product (Code)					
Factor	A	B	C	D	E	F
Time						
F	0.28	0.18	8.45	0.00	7.20	0.25
significance	nsd	nsd	95%	nsd	95%	nsd
Temperature						
F	0.51	0.17	2.03	0.27	0.70	0.12
significance	nsd	nsd	nsd	nsd	nsd	nsd
Time x Temperature						
F	0.02	0.49	2.43	0.20	1.86	0.22
significance	nsd	nsd	nsd	nsd	nsd	nsd

TABLE 11 - TIME AND TEMPERATURE ANALYSIS FOR PERCENT MOISTURE AS DETERMINED BY RADIANT HEATING METHOD

	Product (Code)					
Factor	A	B	C	D	E	F
Time						
F	6.12	0.05	3.97	0.92	13.1	2.79
significance	95%	nsd	nsd	nsd	95%	nsd
Temperature						
F	1.45	0.210	1.80	0.000	1.82	0.19
significance	nsd	nsd	nsd	nsd	nsd	nsd
Time x Temperature						
F	20.1	2.38	1.35	0.73	8.82	1.98
significance	99%	nsd	nsd	nsd	95%	nsd

The vacuum oven method showed significant differences with time for the strawberries and the passion fruit flavored apple cubes. The radiant heating method showed the same with the addition of significance with time for the cherries and with the interaction of time and temperature for the cherries and the passion fruit flavored apple cubes.

Despite the lack of significance the samples stored at 100 °F appear to have lost moisture when compared to those stored at 40 °F and 70 °F.

The radiant heating method is done at 150 °C (302 °F) with either whole pieces or large chunks of fruit. The vacuum oven method is done at 70 °C (158 °F) and with finely ground samples. Because the temperature difference is large, it would be expected that the radiant heating method would drive off more moisture and volatiles. The discrepancy in moisture values obtained by the two methods can be explained primarily by the difference in temperature and also by the size of the sample.

D. Color Measurements

Tables 12, 13 and 14 presents the Hunter "L", "a" and "b" values.

TABLE 12. HUNTER "L" VALUES

Storage Temp. °F	Storage Time, mo	Product (Code) A	B	C	D	E	F
NA	0	19.1	18.5	18.9	43.5	27.1	34.1
120	1	21.7	23.0	22.0	38.8	24.6	32.6
100	1	21.1	21.4	21.1	40.2	24.8	31.8
70	1	20.2	19.6	20.9	40.7	28.4	41.6
40	1	31.5	30.2	33.7	61.4	40.0	51.0
100	3	17.7	18.9	19.7	38.6	23.5	34.1
70	3	20.3	21.3	21.3	40.5	28.0	35.1
40	3	18.9	19.1	20.4	41.0	28.1	36.8
100	6	13.0	13.0	12.7	33.5	15.8	26.8
70	6	16.5	9.5	14.3	35.4	21.2	31.7
40	6	15.1	10.8	12.0	42.5	24.8	37.4

(Continued)

Mean of Data by Time and Temperature °F						
1 mo	24.3	23.7	25.2	47.4	31.1	41.5
3 mo	19.0	19.8	20.5	40.0	26.5	35.3
6 mo	14.9	11.1	13.0	37.1	20.6	32.0
100	17.3	17.8	17.8	37.4	21.4	30.9
70	19.0	16.8	18.8	38.9	25.9	36.1
40	21.8	20.0	22.0	48.3	31.0	41.7

TABLE 13. HUNTER "a' VALUES

Storage Temp. °F	Storage Time, mo	Product (Code) A	B	C	D	E	F
NA	0	5.6	8.2	1.8	8.6	10.5	12.1
120	1	0.7	0.2	0.9	8.5	4.9	8.9
100	1	2.3	0.1	0.9	9.1	7.5	9.1
70	1	4.6	0.2	1.6	8.0	9.7	11.4
40	1	9.6	0.1	4.0	12.7	13.9	17.8
100	3	1.5	0.2	0.9	9.0	6.1	9.3
70	3	4.6	0.2	1.9	7.4	9.1	11.8
40	3	4.5	0.3	2.2	7.9	10.7	12.8
100	6	2.6	1.9	3.6	10.3	7.7	10.7
70	6	6.5	2.9	3.6	8.7	12.5	11.1
40	6	10.6	2.5	6.1	9.6	13.5	12.5
Mean of Data by: Time and Temperature °F							
1 mo		5.5	0.1	2.2	9.9	10.4	12.8
3 mo		3.5	0.2	1.7	8.1	8.6	11.3
6 mo		6.6	2.4	4.4	9.5	11.2	11.4
100		2.1	0.7	1.8	9.5	7.1	9.7
70		5.2	1.1	2.4	8.0	10.4	11.4
40		8.2	1.0	4.1	10.1	12.7	14.4

TABLE 14. HUNTER "b" VALUES

Storage Temp. °F	Storage Time, mo	Product (Code) A	B	C	D	E	F
NA	0	1.9	-0.8	0.9	16.2	7.5	11.1
120	1	0.3	-0.2	0.7	13.2	4.1	9.8
100	1	0.8	-0.6	0.4	14.4	6.0	9.8
70	1	2.2	-0.5	0.7	14.2	7.0	14.2
40	1	3.2	-1.3	0.9	21.9	9.5	15.1
100	3	0.7	-0.4	0.9	14.8	4.8	11.3
70	3	2.1	-0.4	1.4	14.2	7.5	11.4
40	3	0.9	-0.7	1.0	15.0	7.9	11.9
100	6	0.6	-0.7	1.5	14.7	4.5	11.3
70	6	3.2	-1.0	1.5	15.1	9.4	11.7
40	6	3.7	-1.0	3.0	16.6	9.6	13.7
Mean of Data by Time and Temperature °F							
1 mo		2.1	-0.8	0.7	16.8	7.5	13.0
3 mo		1.2	-0.5	1.1	14.7	6.7	11.5
6 mo		2.5	-0.9	2.0	15.5	7.8	12.2
100		0.7	-0.6	0.9	14.6	5.1	10.8
70		2.5	-0.6	1.2	14.5	8.0	12.4
40		2.6	-1.0	1.6	17.8	9.0	13.6

Tables 15, 16 and 17 are the data analysis for the Hunter reflectance color values.

TABLE 15. TIME AND TEMPERATURE ANALYSIS OF HUNTER "L" VALUES

Factor	Product (Code) A	B	C	D	E	F
Time						
F	28.8	70.4	67.8	11.8	24.3	9.25
Significance	99%	99%	99%	99%	99%	99%
Temperature						
F	20.3	28.8	36.2	18.5	38.8	18.8
Significance	99%	99%	99%	99%	99%	99%
Time x Temperature						
F	7.75	18.8	21.9	4.04	3.79	2.3
Significance	99%	99%	99%	95%	95%	nsd

TABLE 16. TIME AND TEMPERATURE ANALYSIS OF HUNTER "a" VALUES

	Product (Code)					
Factor	A	B	C	D	E	F
Time						
F	1.97	25.7	7.94	5.69	0.18	16.6
Significance	nsd	99%	99%	95%	nsd	99%
Temperature						
F	3.27	0.53	5.66	6.69	22.4	43.2
Significance	nsd	nsd	95%	95%	99%	99%
Time x Temperature						
F	0.12	2.03	0.19	5.94	0.03	13.9
Significance	nsd	nsd	nsd	95%	nsd	99%

TABLE 17. TIME AND TEMPERATURE ANALYSIS OF HUNTER "b" VALUES

	Product (Code)					
Factor	A	B	C	D	E	F
Time						
F	1.77	0.88	8.46	6.44	2.49	1.28
Significance	nsd	nsd	99%	95%	nsd	nsd
Temperature						
F	3.25	8.86	0.022	13.8	7.87	6.00
Significance	nsd	99%	nsd	99%	99%	95%
Time x Temperature						
F	0.88	1.98	1.94	4.95	1.77	1.14
Significance	nsd	nsd	nsd	95%	nsd	nsd

For the "L" values the data analysis indicates that all the products have darkened with both time and temperature of storage. This is shown in the data.

For the "a" values the results are less pronounced. Blueberries, strawberries, mango-flavored apple cubes and flavored apple chips all show differences with time of storage, but there is no general trend. All but the cherries and blueberries show differences with temperature of storage with a general decrease in value with increased temperature of storages. In addition time-temperature interactions occurred with mango flavored apple cubes and flavored apple chips.

For the "b" values the strawberries and mango flavored apple cubes show differences with time of storage, with no general trend except that the values tended to lessen between 1 and 3 months and then increase at 6 months. All but the cherries and strawberries showed differences with temperature of storage with an apparent general decrease with increased storage temperature. Also, time-temperature interactions again occurred with the mango-flavored apple cubes.

It appears that temperature of storage is more important then time.

The physical data are plotted in Figures 5 - 10.

Conclusions

Osmotic drying with nutrient infusion appears to be a viable process to prepare fruit for use as military meal item components. If the criterion of a minimum overall aceptability score of 5.5 after 1 month of 120 ^{o}F is used, the cherries, blueberries and mango-flavored apple cubes would all be acceptable. All the products have held up well on storage with some changes appearing at the later times.

We will continue to make withdrawals for testing at all three temperatures at 3-month intervals.

The next phase of the program will be to prepare representative products (cherries and mango-flavored apple cubes) with folic acid and magnesium and zinc, added by infusion during the osmotic drying.

References

Cohen, Joseph and Yang, Tom, C.S. Sept. 1995. Osmotic Dehydration And Its Applications In Nutrient Infusion of Various Foods. Technical Report, UA Army, Natick Research, Development and Engineering Center /TR-95/034,

A.O.A.C. 1995. Official Methods of Analysis. Moisture. Chapter 37. Fruits and Fruit Products. Moisture in Dried Fruits

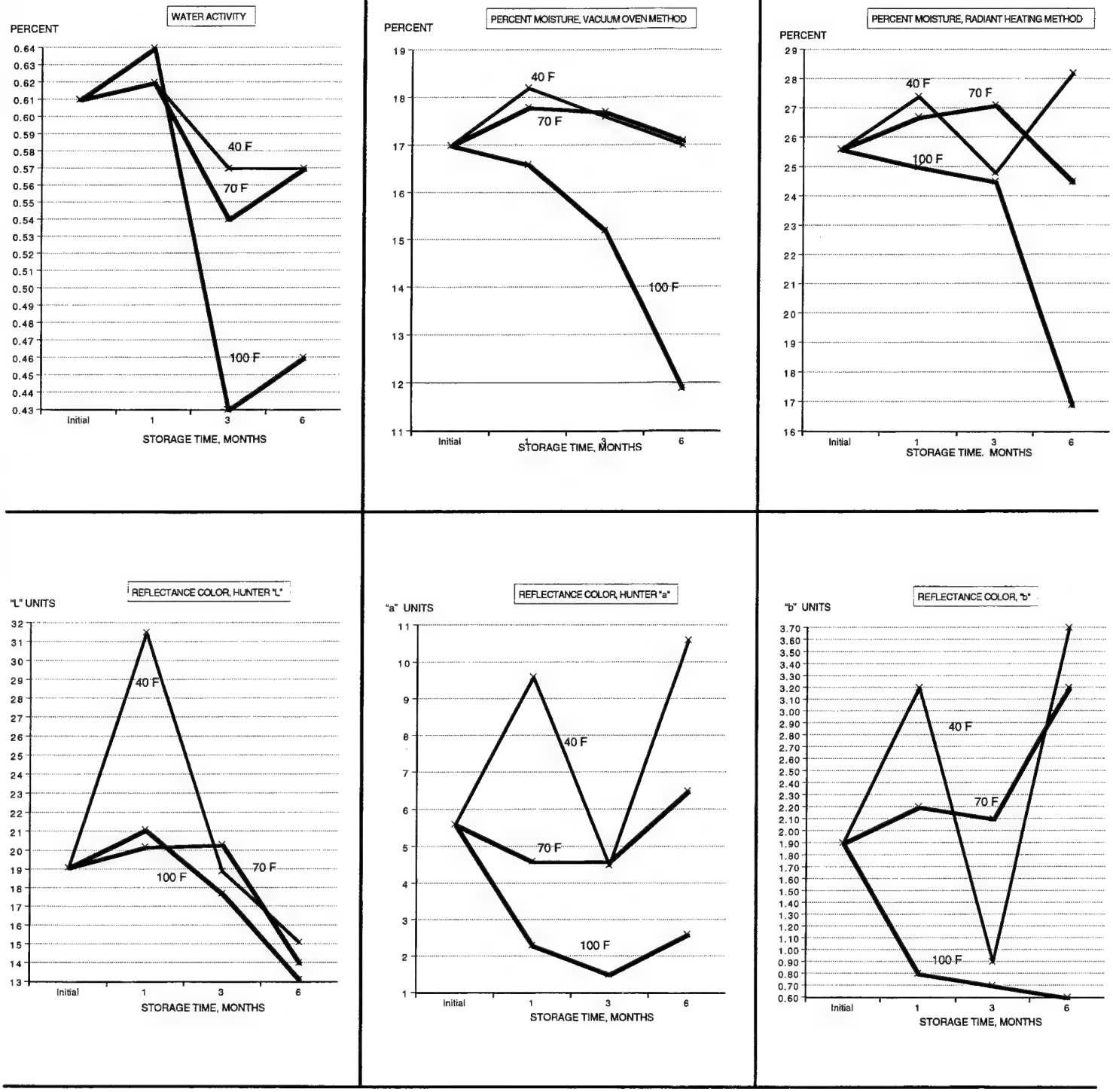


FIGURE 5 - CHERRIES, PHYSICAL DATA

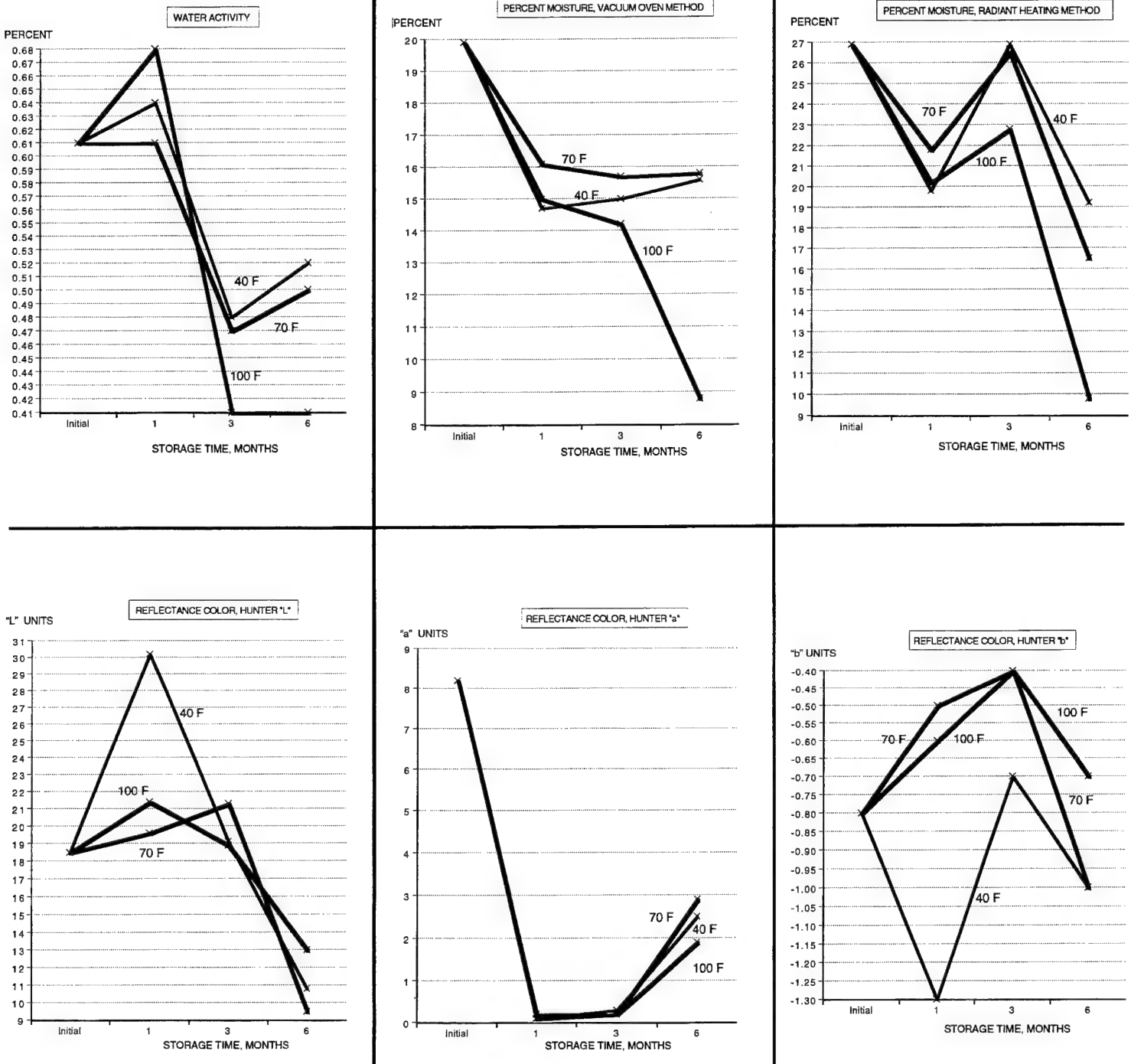
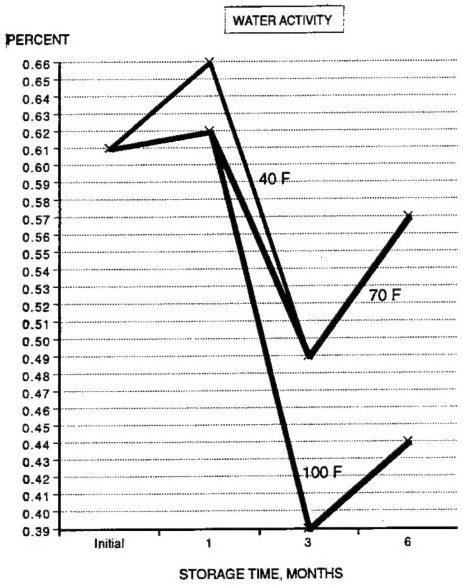
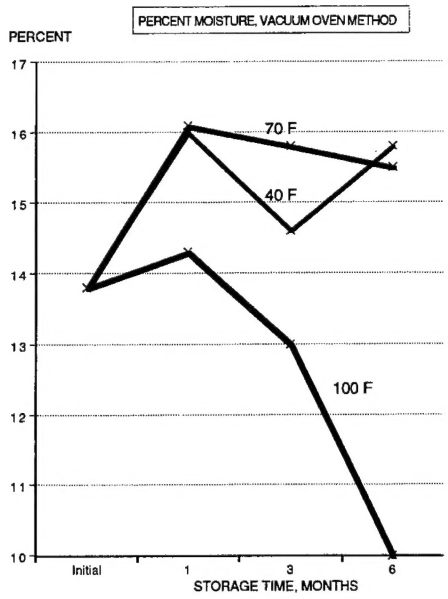
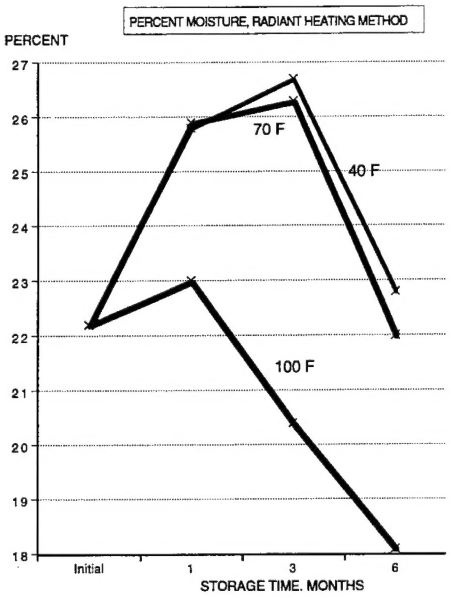
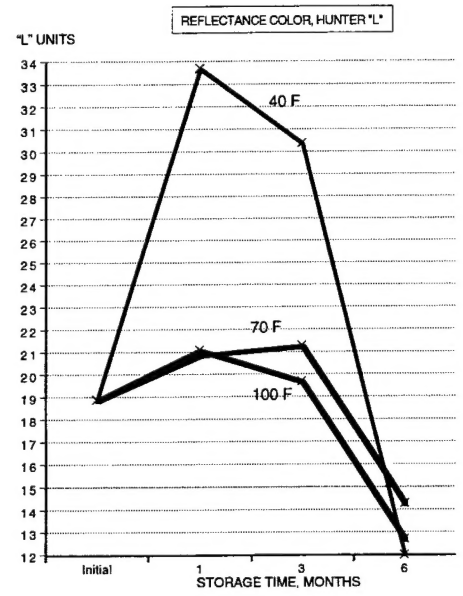


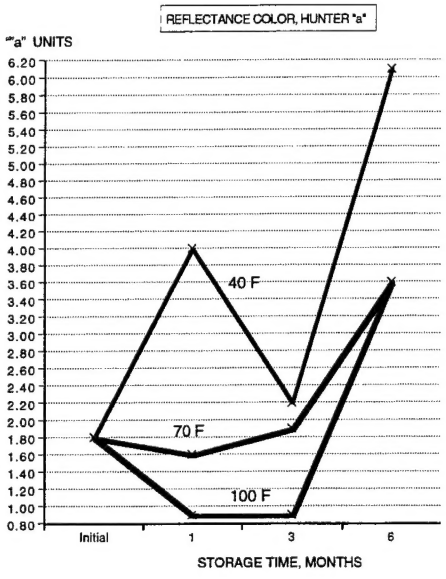
FIGURE 6 - BLUEBERRIES, PHYSICAL DATA











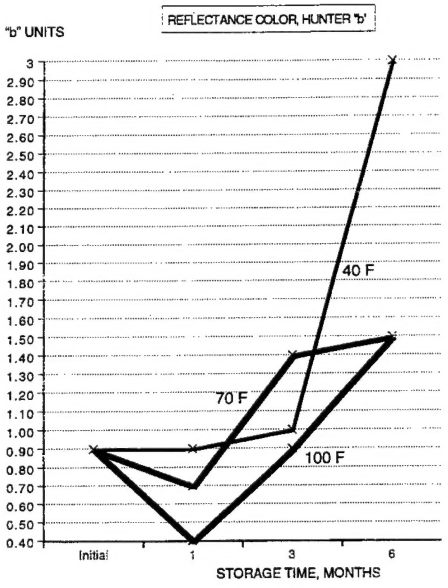


FIGURE 7 - STRAWBERRIES, PHYSICAL DATA

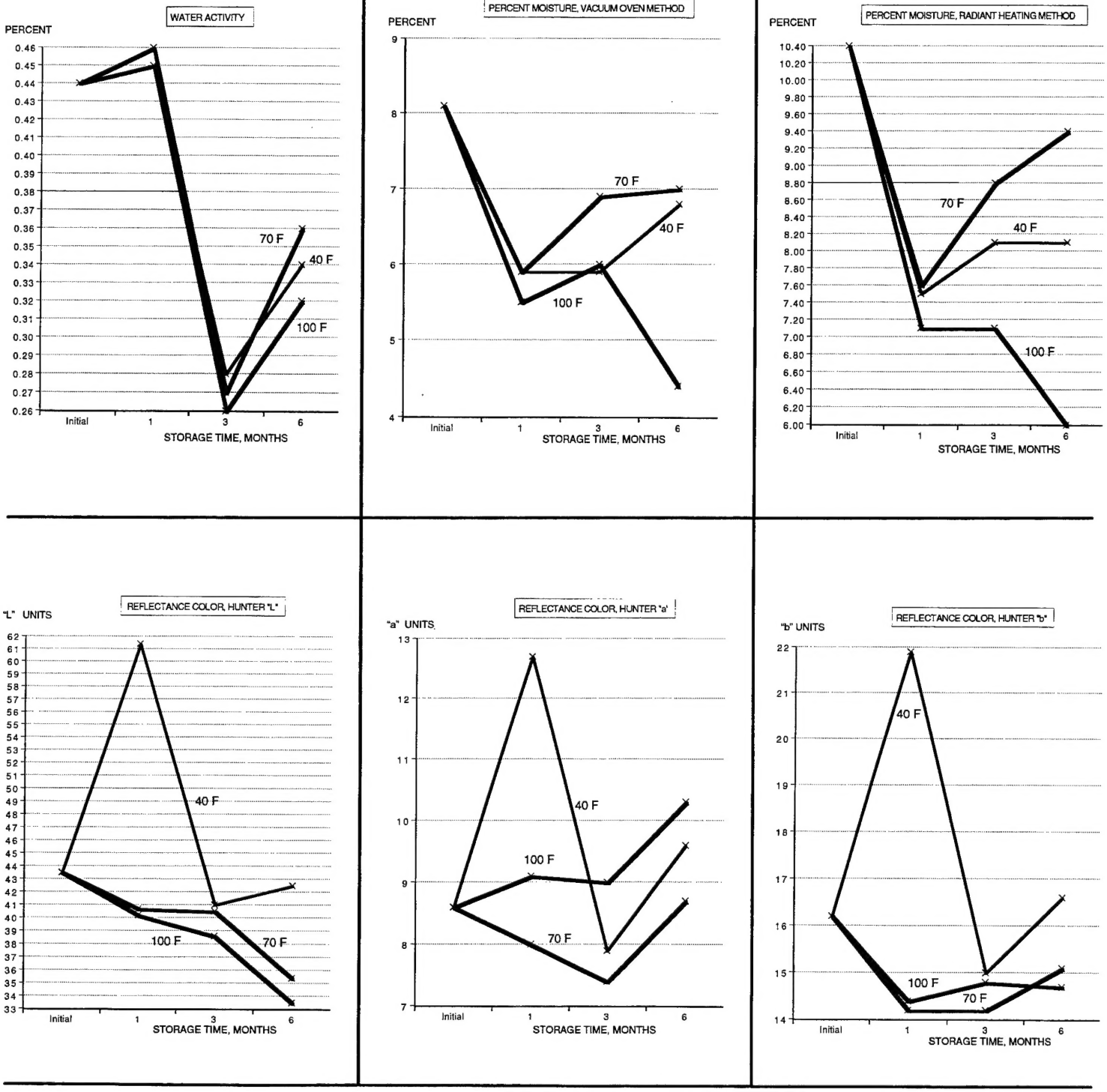


FIGURE 8 - MANGO-FLAVORED APPLE CUBES, PHYSICAL DATA

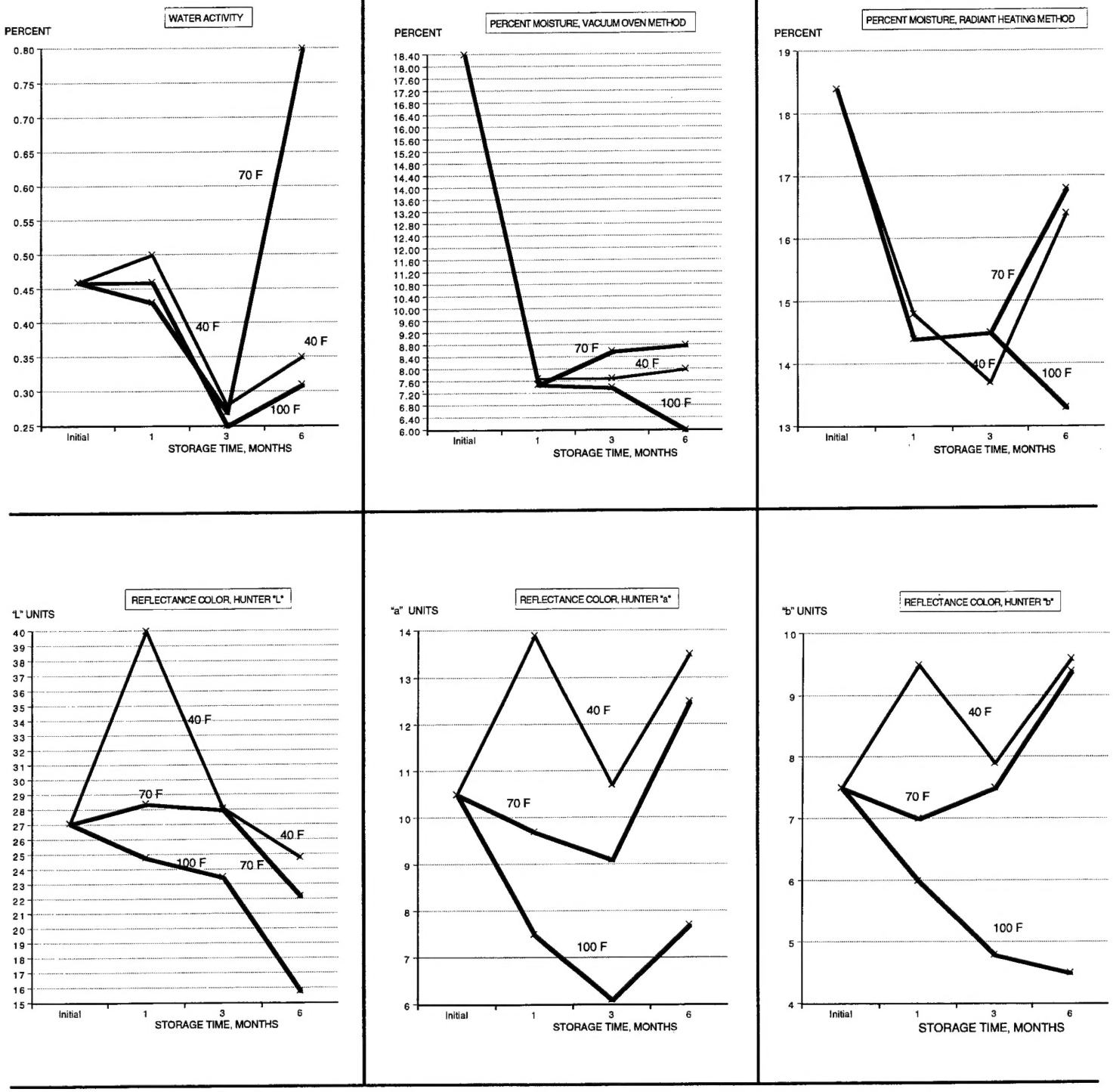
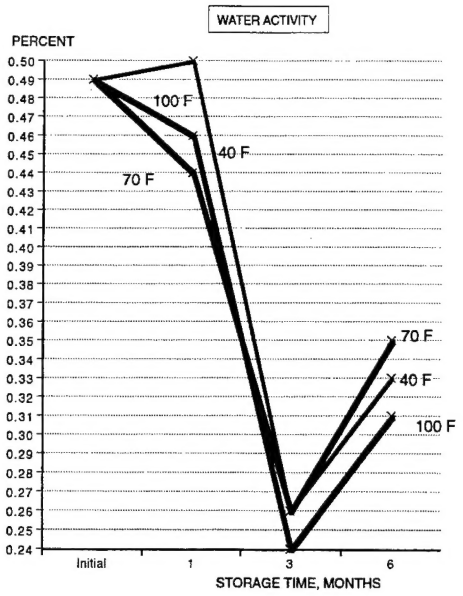
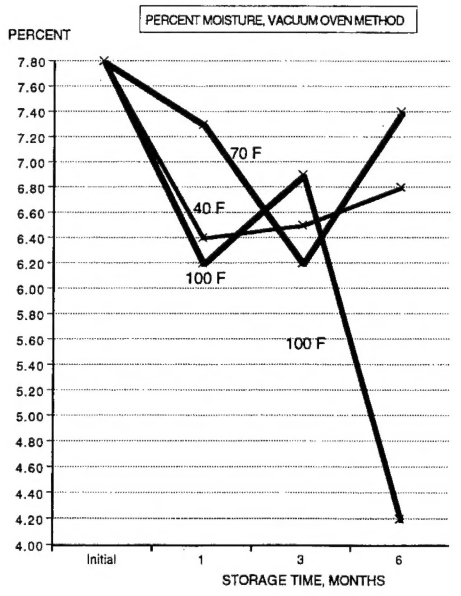
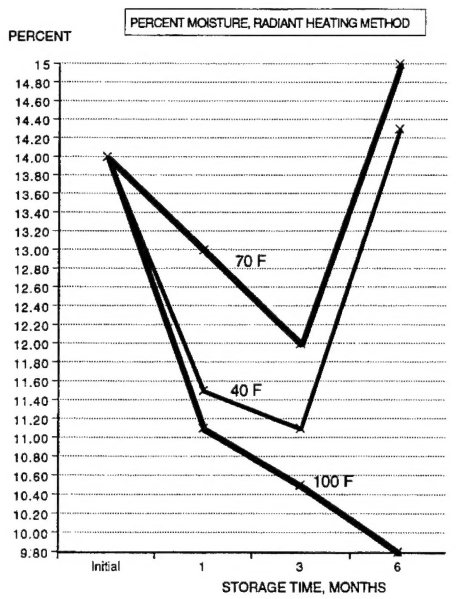
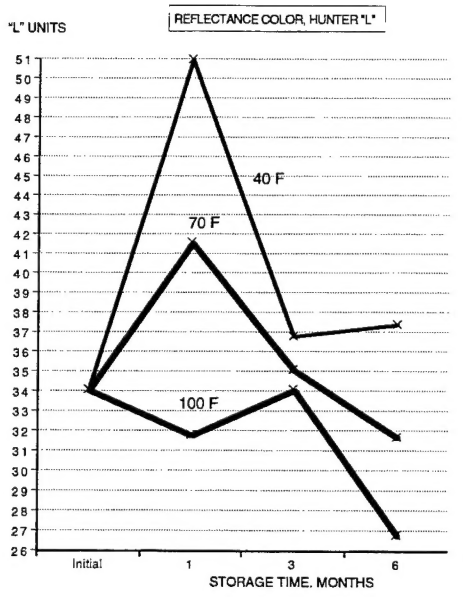


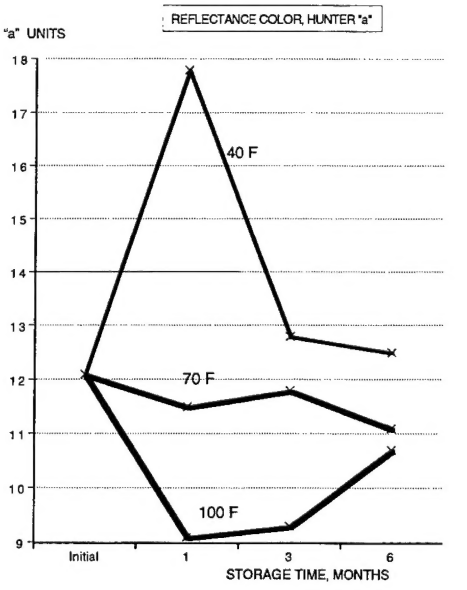
FIGURE 9 - PASSION FRUIT/CHERRY-FLAVORED APPLE CUBES, PHYSICAL DATA











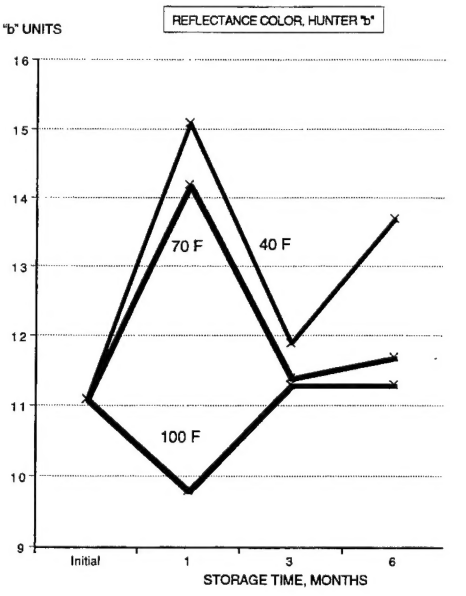


FIGURE 10 - CINNAMON/CHERRY FLAVORED APPLE CHIPS, PHYSICAL DATA